Jo Buckberry*, Janet Montgomery, Jacqueline Towers, Gundula Müldner, Malin Holst, Jane Evans, Andrew Gledhill, Naomi Neale and Julia Lee-Thorp

FINDING VIKINGS IN THE DANELAW

*Corresponding author. Email j.buckberry@bradford.ac.uk

SUMMARY

Historical, artefactual and place-name evidence indicate that Scandinavian migrants moved to eastern England in the ninth century AD, settling in the Danelaw. However, only a handful of characteristically Scandinavian burials have been found in the region. One, widely held, explanation is that most of these Scandinavian settlers quickly adopted local Christian burial customs, thus leaving Scandinavians indistinguishable from the Anglo-Saxon population. We undertook osteological and isotopic analysis to investigate the presence of first generation Scandinavian migrants. Burials from Masham were typical of the later Anglo-Saxon period and included men, women and children. The location and positioning of the four adult burials from Coppergate, however, are unusual for Anglo-Scandinavian York. None of the skeletons revealed inter-personal violence. Isotopic evidence did not suggest a marine component in the diet of either group, but revealed migration on a regional, and possibly an international, scale. Combined strontium and oxygen isotope analysis should be used to further investigate both regional and Scandinavian migration in the later Anglo-Saxon period.

The lack of burial evidence of Scandinavian settlers within the Danelaw has been long debated; less than 30 Viking burial sites, many just single graves, have been identified in England (Richards, 2000, 142). This is despite the wealth of archaeological and historical evidence for Scandinavian settlement. The first Scandinavian activities reported in England were the raids of the late eighth and early ninth centuries (documented in the Anglo-Saxon Chronicle for the years AD 793, 794, 835 and 836). From AD 850, Scandinavian armies began to overwinter in England, and by the 870s Scandinavians began to settle in earnest (Hadley, 1997, 69, Richards, 2000, 23, 27, Hall, 2000). The Danelaw was first referred to in a law of Æthelred in AD 1008, describing an area where Scandinavian laws were used rather than Mercian or West Saxon laws. The term has subsequently been employed to describe an area strongly influenced by Scandinavian settlement, characterised by a different social structure and estate system, the use of Scandinavian legal and administrative terms, and a prevalence of Scandinavian place names and Scandinavian-style artefacts, as well as imports from both Scandinavia and areas of Viking trade and settlement (Hadley, 1997, 70, Hall, 2000). The Danelaw is geographically defined by the rivers Thames, Lea and Ouse and the Roman Road known as Watling Street, based on a treaty between the Viking leader Guthrum and Alfred of Wessex, c. AD 886-90 (Hall, 2000, 147). The region was occupied by people of both Scandinavian and Anglo-Saxon descent from the late ninth century, and was under fluctuating Scandinavian and English rule during the late ninth and tenth centuries, until the Norman conquest (Hadley, 1997, 88). Rather than a single event that defines the start of the Anglo-Scandinavian period, small-scale migration appears to have occurred throughout this period of settlement.

Migrating people have been traditionally identified by the presence of burial rites and artefact types that are clearly different from those of the local, indigenous population. The assumption that differences in burial rite indicate a migratory population has been particularly prevalent for the later Anglo-Saxon period, when the inclusion of *any* grave goods whatsoever (be these Scandinavian or Anglo-Saxon in origin) from the ninth century onwards – a time when grave good deposition was unusual – has been considered enough evidence for some researchers to identify these graves as Scandinavian (for examples and further discussion see Halsall, 2000, 263-268). This approach stems from the long-held view that the Anglo-Saxon Church frowned upon grave good deposition, and therefore the inclusion of grave goods was a pagan practice; which in turn suggests that any burial with graves goods was that of a (pagan) Viking. Halsall argued that burial rites can only be used to confidently identify migrants where the new burial rites have a direct link with those used in the homeland, the comparable rites in the homeland are chronologically earlier, and the newly introduced rites differ significantly from those of the indigenous population (Halsall, 2000, 262). In later Anglo-Saxon England, burial rites are diverse and grave good deposition continued, albeit occasionally, even in Christian contexts (Hadley, 2000). Thus, the deposition of grave goods *per se* does not necessarily indicate that the individual buried with them was either pagan or of Scandinavian descent (Halsall, 2000, 262-268). That said, some of the purported Scandinavian graves in England are sufficiently distinct for Scandinavian identity to be likely. The most convincing contender is the barrow cemetery containing cremated individuals and Scandinavian artefacts at Heath Wood, Ingleby, Derbys (Richards et al., 1995, Richards, 2004); at this time, cremation is an intrusive rite in England but was practiced in Sweden, Norway and northern Jutland. Other contenders for Scandinavian identity include isolated accompanied burials such as that of that of a woman buried with Scandinavian artefacts at Adwick-le-Street, S Yorks (Speed and Walton Rogers, 2004), barrow burials with Scandinavian grave goods, e.g. Bedale and Camphill, both Yorks (see below) and burials within churchyards that contain distinctively Scandinavian artefacts, for example the burial containing many grave goods including a Scandinavian sword and a silver pendant in the shape of Thor's hammer at Repton, Derbys (Biddle and Kjølbye-Biddle, 1992, 2001). Some of these individuals have been subjected to isotope analysis, which has suggested that they were migrants, and possibly from Scandinavia (Budd et al., 2004, Speed and Walton Rogers, 2004).

Even without a more rigorous interpretation of grave good evidence, the corpus of probable Viking burials in England is small, prompting Halsall to suggest that if it were representative of the number of Scandinavian immigrants, it "would reduce the *Micel Here* [great army] to almost 'Magnificent Seven' proportions" (Halsall, 2000, 269). Thus, it has become widely accepted that many of the Scandinavians who eventually settled in northern and eastern England must have been buried in established late Anglo-Saxon cemeteries in Christian style graves (Halsall, 2000, 270, Richards, 2000, 151). This does not necessarily mean these Scandinavians were all Christians; indeed we have been cautioned from conflating the act of conversion from the much longer process of Christianisation (Abrams, 2000, Richards, 2003). Rather, their choice in burial rites probably reflects a deliberate display of their allegiance with the indigenous population (Hadley, 2002, 67-68). Whatever the meaning behind this use of local burial form, it renders many of the Vikings archaeologically invisible. Whilst the investigation of overtly Scandinavian graves and their inhabitants is an important line of enquiry, for us to assess the number of Scandinavians who migrated to, and died in, England, we must start to investigate a wider range of burial types. Indeed, evidence from Scandinavia reveals burial practices were diverse and some of those employed would not necessarily look out of place in northern England; thus even when employing Scandinavian traditions in a new land, burials may not look distinctive (Hadley, 2006, 253-254).

Here we present two case studies from Yorkshire that highlight the integration of archaeology, osteology and isotope analysis to investigate the presence of first generation Scandinavian settlers within the northern Danelaw. The first, Masham, deals with a mixed population, all of whom were buried in a manner typical of later Anglo-Saxon cemeteries; the second focuses on a small cluster of unusual burials from the heart of Anglo-Scandinavian York. Isotope evidence indicates that both groups included potential Scandinavian settlers, but in both cases, no distinctive Scandinavian artefacts were recovered from the graves.

Our approach attempts to identify individuals who grew up in one region and settled in another; it cannot establish with certainty where an individual was born, but it can ascertain if this location was consistent with that of burial, and if found to be non-local, it can exclude wide geographical areas. More importantly, it cannot be used to identify the ethnicity of the individual. Ethnicity is culturally defined, can change or be manipulated throughout an individual’s lifetime, and may be perceived differently by outsiders (Curta, 2007, Jones, 1997, Lucy, 2005). Thus, while contributing to the investigation of population movement, in time, isotope analysis may shed more light on the complex manner in which ethnic identity was created and expressed in early medieval Europe.

SCANDINAVIAN BURIAL AROUND MASHAM

Masham is a small town in lower Wensleydale, North Yorkshire (Figure 1). Archaeological evidence of burial dating to the mid to late Anglo-Saxon period in the region is well represented, with multiple cemeteries in both York and Ripon and further cemeteries spread across the county (Buckberry, 2010). Three discoveries of Scandinavian artefacts from around Northallerton (Yorks) are believed to be from burials. However, each of these was discovered before reliable archaeological recording and the descriptions of the extant evidence are sketchy at best. These include a pair of oval brooches found at Romanby on the outskirts of Northallerton which reputedly came from an inhumation burial, however “no further information [was] available” about the discovery (Bjørn and Shetelig, 1940, 15, 19). A pair of tenth-century oval brooches has also been found at Bedale, approximately half-way between Masham and Northallerton. It is possible that these may have come from a second Scandinavian burial in the area (Bjørn and Shetelig, 1940, 77, 105-106), although in this case there is no reference to a skeleton associated with the brooches. Richards noted that an inhumation burial accompanied by a sword and a spear was discovered in a natural mound at Camphill, Bedale, and suggests that this is evidence of another distinctively Scandinavian burial in the region (Richards, 2000, 145). Although the two site names (Bedale and Camphill, Bedale) are similar, leading to the possibility that a single discovery could have been conflated into two separate finds, the grave goods belong to mutually exclusive groups traditionally associated with different genders, supporting the argument that these reports are of two separate discoveries. Thus, there appears to have been at least three graves containing Scandinavian artefacts in the Bedale area, immediately northeast of Masham. In 1915, grave diggers found a burial with an iron sword, spearhead, sickle and knife in Wensley churchyard, 18 km northeast of Masham. The burial has been interpreted as that of a Scandinavian on the basis of the presence of grave goods, although the sword was of Anglo-Saxon, not Viking manufacture (Morris, 1981, Richards, 2000, 150, Halsall, 2000, 264).

The Masham Cemetery

The Dixon Keld cemetery in Masham was first discovered in 1985, with small scale excavation taking place in 1988 and 1989 by Mary Kershaw for Harrogate Borough Council (MSM WC88) and by Kevin Cale on behalf of Yorkshire Water Authority (MSM89); the two excavations revealed 58 graves. Neither excavation provided funding for post-excavation analysis; the present research was undertaken by a team from the University of Bradford on behalf of Harrogate Museum and Arts between 2005 and 2008.

The cemetery is located close to the market square and approximately 170m from St Mary's parish church. The Domesday Book records a church in Masham in AD 1086. The standing church is Norman and later, although Taylor and Taylor (1965, 734) recorded pre-Conquest fabric within the north aisle. Various fragments of Anglo-Saxon stone sculpture have been found in and around the church, including a columnar shaft, which has been interpreted as a cross base. Four of the sculpture fragments have been dated to the late-eighth- to ninth-centuries, one to the ninth- to tenth-centuries and one, a grave marker or shaft fragment, to the mid-eleventh century (Lang, 2001, 168-174).

The Masham burials were west-east aligned with heads to the west and were extended and supine. One skeleton (MSM89 XVIII) was noted by the excavators as having been buried in a "contorted position” (Anon, 1989). The vertebral column was curved, the forearms were crossed over the abdomen with the right hand clutching the left forearm; the left lower limb “was arranged in a peculiar fashion” (Anon, 1989), although it is unclear if this was due to deliberate placement of the body, disturbance of the grave or a pathology not identifiable on the surviving bones. Several river worn cobbles and sandstones were located on either side of this burial (Anon, 1989). Sadly no plan or photograph of this burial have been identified in the site archive.

No grave goods were present in any of the graves; a small bronze pin was present in the grave of skeleton MSM89 XI was probably either a dress pin or a shroud pin (Anon, 1989). No evidence of wooden coffins was recovered; however several burials were in stone-lined graves, a burial practice common in the tenth to twelfth centuries in Yorkshire (Buckberry, 2004). An area of rough sandstone slabs may be plain covers above further graves. The Masham cemetery was interpreted by the excavators as an early medieval Christian cemetery, dating to the seventh to eighth centuries AD (Anon, 1989). No evidence of a church within the Dixon Keld cemetery was encountered during either the 1988 or 1989 excavations.

Overall, the evidence supports a mid to late Anglo-Saxon date for the cemetery. While unaccompanied, west-east aligned, supine and extended burials can conceivably date to many archaeological periods, the location of the cemetery – within the settlement and a few hundred metres of the church – has consistently been shown to be typical of mid to later Anglo-Saxon cemeteries, especially those not believed to have had a church (Buckberry, 2010). Likewise the presence of stone-lined graves, plain stone grave covers and shroud pins are all consistent with a later Anglo-Saxon date (Buckberry, 2007, Hadley, 2001, Hadley and Buckberry, 2005). Radiocarbon dates revealed that the cemetery was probably in use from the late seventh to eighth century to the tenth to early eleventh centuries AD (see Table 1). Although the cemetery was founded prior to the first Scandinavian settlement of the region, it continued to be used throughout the later Anglo-Saxon/Anglo-Scandinavian period and is a possible final resting place for Scandinavian migrants to this area of north Yorkshire.

ANGLO-SCANDINAVIAN BURIAL IN YORK

York contains a large number of excavated burial sites that date to the Anglo-Scandinavian period. Most of these are churchyards: York Minster (excavated burials are believed to relate to the original

Minster of St Peter's), St Andrew's Fishergate, St Helen-on-the-Walls, St Mary Bishophill Senior, St Mary Bishophill Junior; or are burials believed to be associated with a churchyard: Swinegate (St Benet's) and Florence Row (St Mary Bishophill Junior) (Buckberry, 2010). Burials not associated with a church are more unusual and include eighth-century burials from Spurriergate in York (MAP Archaeological Consultancy, 2005), those excavated at Lamel Hill/Belle Vue House, tentatively dated to the mid to late Anglo-Saxon period on the basis of what appear to be coffin fittings on illustrations from the nineteenth-century excavations (Thurnam, 1849), and those from Castle Yard, dated to the ninth to tenth centuries based on the presence of a ninth-century styca (York Archaeological Trust, 1998).

As the political centre of the Danelaw, it is expected that many Scandinavians settled, and were therefore buried, in York. Historical records of burial reveal that of the 14 named individuals buried within the city, three were of Scandinavians: King Swein (d. 1014, buried at St Peter's); Earl Siward (d. 1055, buried at St Olave's); and Earl Tostig (d. 1066, buried 'in York') (Buckberry, 2007, 119). Archaeological evidence offers some tantalising clues of Scandinavian burial in York. Burials dating to the ninth to tenth centuries excavated at St Mary Bishophill Junior were accompanied by an arm-ring, a silver penny, an iron knife, a whetstone and a copper-alloy buckle (Wenham et al., 1987, 75-83). In addition, one of the burials from Florence Row, located just outside the churchyard of St Mary Bishophill Junior, was associated with a fragment of a silver arm ring, although this deposit was disturbed making it impossible to establish the relationship between the skeleton and the arm ring (Wenham et al., 1987). Finally, burials at York Minster included one individual buried in a boat and further burials with stone grave covers with Scandinavian-style decoration, clearly indicating Scandinavian influences (Phillips and Heywood, 1995).

The Coppergate Burials

Possibly the most intriguing burials dating to Anglo-Scandinavian York were the four found during the excavation of the settlement at Coppergate (Hall, 2014). Two burials were largely articulated and were deposited in pits dated stratigraphically to the ninth century and radiocarbon dated to the late-seventh to ninth centuries (Table 1). Their position is unusual at a time when supine and extended burial was the norm; one was buried with their left upper limb flexed with the hand behind the cranium and the elbow in front of the face, and with the right upper limb positioned away from the body on the left side (Figure 2). The lower limbs have been partly disturbed post-mortem, but these appear to have been flexed to the right. The second skeleton was located only 1.8 m from this individual and was interred in a similar position. A third ninth-century pit contained a partial disarticulated skeleton (Richard Hall, *pers. comm.*). The fourth Coppergate burial was located some distance from the others, in close proximity to the River Foss. This burial is slightly later, dating to the late-ninth to early-eleventh centuries AD. This individual had received more formal burial than the others, having been interred in a shallow grave in a supine and extended position and an east to west orientation. It has been previously noted that the unusual form and location of these burials within a town well-endowed with churchyard cemeteries is striking, and a possible Scandinavian origin for these individuals was hypothesised (Buckberry, 2010).

THE MASHAM POPULATION

Age and sex were assessed using standard osteological methods (Buikstra and Ubelaker, 1994, Bass, 1995, Phenice, 1969, Moorrees et al., 1963a, 190-194, Moorrees et al., 1963b, Smith, 1991, Hillson, 1986, Maresh, 1970, Scheuer and Black, 2000, Brothwell, 1972, Suchey et al., 1988, Buckberry and Chamberlain, 2002, Lovejoy et al., 1985, Meindl and Lovejoy, 1985, İşcan et al., 1984, İşcan et al., 1985). Sex could be assessed for 40 adults. Of these, 19 were male or probable male, and 21 were female or probable female. The Masham population included sub-adults and adults of all age groups (see Figure 3), but with some underrepresentation of infants; a finding typical of a lay population dating to the later Anglo-Saxon period (Buckberry, 2004).

The Masham population was examined for evidence of pathology (Ortner, 2003, Aufderheide and Rodríguez-Martín, 1998, Rogers and Waldron, 1995, Roberts and Manchester, 2005). Dental pathologies including caries, calculus, abscesses, apical granulomas and periodontal disease were common within the population, while just one individual had enamel hypoplasia; in this case a rare form of hypoplasia termed cuspal enamel hypoplasia (CEH) (Ogden et al., 2007), which affects large areas of the enamel compared with the more common linear form. Non-specific indicators of physiological stress within the sample included cribra orbitalia and sub-periosteal bone formation; the latter was more commonly of woven bone within the sample, indicating the condition was active at the time of death, although it should be noted that this does not necessarily mean the condition contributed to the cause of death. Spinal joint disease – both osteoarthritis of the synovial joints and intervertebral disc disease – was prevalent in the population, as were Schmorl's nodes. Fractures were present in eight individuals; all of these were healed and the degree of alignment of a fracture to the radius and ulna of one individual suggests that splints were used to treat them. Interestingly, three individuals exhibited healed trauma to their spines. This, combined with the evidence of Schmorl's nodes, suggests that a portion of the population at least was probably involved in activities that included heavy loading to the spine. No evidence of interpersonal violence was recorded (Neale and Buckberry, 2008). Overall, the pattern of pathology is consistent with a peaceful population and with other populations of the period.

THE COPPERGATE SKELETONS

The Coppergate skeletal remains were examined using a slightly different selection of standard techniques (Buikstra and Ubelaker, 1994, Cox, 2000, Mays and Cox, 2000, Scheuer and Black, 2000). The four individuals included two females: a young adult (19-25 years old) and a mature adult (46+ years), and two males: one aged 36 to 45 years and the second aged over 18 years.

Pathological analysis of the skeletons was undertaken using established criteria (Aufderheide and Rodríguez-Martín, 1998, Barnes, 1994, Ortner, 2003, Roberts and Manchester, 2005). The older male and female showed evidence for a variety of minor congenital anomalies, most of which affected the spine. The mature female also had congenital hip dysplasia, which had caused shortening of one lower limb and presumably a limp, formation of an artificial hip joint with secondary osteoarthritis, atrophy (wasting) and inflammation of the affected lower limb and hip, over-use of the opposite lower limb causing muscular trauma and osteoarthritis and one-sided degenerative joint disease and osteoarthritis of the spine. The fact that she had unusually robust arms and shoulders, as well as degenerative joint disease in the shoulders, hips and right hand may suggest that she used crutches.

The old middle adult male also had number of congenital defects, including a cleft spinous process of the first sacral vertebra and distorted sternum. He suffered from degenerative joint disease of the spine shoulders, hips and ribs and spinal osteoarthritis and had periosteal inflammation of the lower limbs and skull. Both males showed evidence for damage or restriction to their blood supply, seen in the left elbow of the male adult and the heel bones of the old middle adult. Spinal disc problems in the form of Schmorl's nodes were noted in all three individuals with spines. The young adult female showed evidence for cribra orbitalia. The dental health of the population was moderate, with widespread calculus, indicative of poor oral hygiene. Dental abscesses were more prevalent than the early medieval average, while the frequency of cavities and ante-mortem tooth loss was lower (Holst, 2010, 2014).

ISOTOPIC ANALYSES

Three different types of isotopic analysis were employed in this study. The first involved the measurement of carbon and nitrogen isotope ratios of collagen, the organic component of bone and dentine, which can be used to assess dietary variability within a population and to provide indications of trophic level within a food web and sources of carbon (e.g. Hedges and Reynard, 2007, Lee-Thorp, 2008, Müldner and Richards, 2007). Given the inland location of both Masham and York, and the fact the burials predate the increase in marine fish consumption in the High Medieval

Period, it would be predicted that indigenous inhabitants of Masham and the surrounding region would have a solely, or predominantly, terrestrial-based diet (Barrett and Richards, 2004, Müldner and Richards, 2007, Barrett et al., 2004). In contrast, whilst it is acknowledged that not all Viking Age individuals in the Scandinavian homelands consumed marine protein (Lidén and Nelson, 1994), diets with a marine component have been identified for some coastal sites in Scandinavia (Kosiba et al., 2007) and inferred for some Scandinavian migrants in Britain as a result of isotopic analysis (Barrett and Richards, 2004, Montgomery et al., in press, Pollard et al., 2012). By analysing both dentine and bone it is possible to compare diet from different stages of life: primary dentine forms during childhood and is not subsequently remodelled (Hillson, 1986); in contrast, bone is continually remodelled, and reflects a long-term dietary average spanning perhaps 10-30 years before death (Hedges et al., 2007). Therefore the isotopic analysis of bone and, particularly, dentine collagen allows us to compare childhood and adult diet. A shift from marine to terrestrial resources over this timescale, or evidence of marine consumption in the bone collagen might indicate possible migrants.

The second type of analysis consisted of oxygen and carbon isotope ratios of the carbonate component of tooth enamel. Oxygen isotope ratios of tooth enamel primarily reflect the isotope composition of drinking water consumed during the period of enamel mineralisation (primarily childhood), although there is some influence from dietary sources (Daux et al., 2008, Longinelli, 1984, Luz and Kolodny, 1985). As a consequence, $\delta^{18}O$ values in enamel convey information about the hydrology of the environment where the individual grew up and exploit the differences between the oxygen isotope ratios of precipitation in England and Scandinavia (Darling et al., 2003, Fricke et al., 1995). Finally, complementary information about geographical origins was obtained from strontium isotope ratios which were also measured in tooth enamel. However, rather than reflecting climate, the strontium isotope ratios are linked to local geology and reflect the type of rocks and soils in the region in which food and water was obtained during childhood (Beard and Johnson, 2000, Ericson, 1985). The age and type of the sedimentary Palaeozoic sandstones and limestones of north-eastern England are very different to the ancient and largely granitic PreCambrian Baltic Shield. The latter can produce far higher biosphere, and hence human, strontium isotope ratios and this difference in geology provides the basis for identifying Scandinavian migrants to England. Thus, oxygen and strontium isotope ratios measured in tooth enamel have the potential to provide information on the residential mobility between the childhood and the death of individuals from Masham and Coppergate, York.

SAMPLES AND METHODS

Carbon and nitrogen isotopes were measured in bone (rib) and dentine collagen; carbon, oxygen and strontium isotope ratios were measured in tooth enamel. The isotope ratios of nitrogen, oxygen and carbon are expressed relative to international standards as δ^{15}N, δ^{18}O and δ^{13}C and units are per mil (‰). Strontium isotope ratios are expressed as ^{87}Sr/^{86}Sr. Analysis was carried out at the University of Bradford (δ^{15}N, δ^{18}O and δ^{13}C), the University of Reading (δ^{15}N and δ^{13}C of the Coppergate skeletons) and at the NERC Isotope Geosciences Laboratory (NIGL), Keyworth, UK (^{87}Sr/^{86}Sr); preparation and measurement were conducted following established laboratory protocols.

RESULTS AND DISCUSSION

Carbon and Nitrogen Isotope Ratios

Collagen results for Masham and Coppergate humans and Masham domestic animals are presented in Tables 2 and 3 and displayed graphically in Figure 4. All collagen samples reported here had C:N ratios within the range 3.1 – 3.5 and yields of at least 0.5%, indicating collagen of acceptable quality (van Klinken, 1999). The domestic animal data from Masham form a reasonably tight cluster apart from the δ^{15}N value of one sheep. The human collagen data from Masham and Coppergate cover a comparatively narrow range (Masham δ^{13}C -21.1‰ to -19.5‰ and δ^{15}N 9.1‰ to 12.3‰ and Coppergate δ^{13}C -20.7‰ to -20.0‰ and δ^{15}N 9.8‰ to 11.4‰) and there is little difference between bone and dentine collagen values from Masham (bone mean δ^{13}C = -20.4 ± 0.3 ‰, δ^{15}N = 10.5 ± 0.7 ‰, 1 sd, n = 37; dentine mean δ^{13}C = -20.4 ± 0.3 ‰, δ^{15}N = 10.7 ± 0.7 ‰, 1 sd, n = 20). The mean values for bone collagen from Masham and Coppergate are virtually identical (Coppergate mean δ^{13}C = -20.4 ± 0.3 ‰; δ^{15}N =10.5 ± 0.9‰, 1 sd, n=3). At the level of the individual, there is no consistent pattern of dietary change between childhood (dentine) and adulthood (bone) in the 15 individuals for whom both tissues were measured. δ^{13}C differences (bone-dentine) of an individual skeleton range from -0.5 to 0.5‰ and the majority (13 of 15) are within analytical error (2 sd), indicating no major change in the source of protein occurred during their lifetimes. δ^{15}N differences between the two tissues in single individuals are larger and range from -1.4 ‰ (signifying a reduction from childhood to adulthood values), to a rise of 0.7 ‰ with roughly half (7 of 15) being within analytical error (2 sd). For the remaining eight individuals, five (MSM88 C, MSM88 F, MSM89 I, MSM88 M, MSM88 S) show a drop in δ^{15}N between childhood and adulthood and three (MSM88 B, MSM88 G, MSM88 I) a rise, with both sexes being represented in both groups. The individuals who display the largest fall in δ^{15}N (-1.4 to -0.9 ‰) have no measurable change in δ^{13}C indicating that the observed change in values cannot be explained through changing access to terrestrial and marine foods but may be explained by changing relative access to different types of terrestrial protein. This, combined with the fact that faunal data from Masham and York (cf. Müldner and Richards, 2007) indicate no differences in 'baseline' values between the sites suggests that, for the individuals included in this study, diet was isotopically similar and there was no major dietary shift between childhood and adulthood. There is a clear trophic level shift between the humans and the animals, observed in both $\delta^{13}C$ and $\delta^{15}N$, indicating that the human diet was predominately terrestrial and probably included domestic animal products. Although it is possible that freshwater resources formed part of the diet, there is no evidence for the consumption of marine foods which would have produced higher $\delta^{13}C$ and $\delta^{15}N$ values (Müldner and Richards, 2007, Barrett and Richards, 2004). A terrestrial diet was expected amongst indigenous inhabitants of Masham and York due to both the date of the burials and their inland location. The human data from Masham and Coppergate are most similar to the mid-late Anglo-Saxon population of Lamel Hill/Belle Vue House from York (Müldner and Richards, 2007) and generally compare very well with isotope data from other, roughly contemporaneous, populations from England (see Pollard et al., 2012). The data are, therefore, somewhat inconclusive: they provide no evidence for marine-protein consumers amongst either population but this is not conclusive evidence that they were not Scandinavian settlers, because not all Scandinavian populations have isotope ratios that indicate a marine-based diet.

Oxygen and Strontium Isotope Ratios

Oxygen and carbon results for enamel carbonate from Masham and Coppergate are presented in Table 4 and displayed graphically in Figure 5. The data for Masham all lie within two standard deviations of the mean values ($\delta^{13}C$ = -14.1 ± 0.9 ‰, $\delta^{18}O$ = 25.7 ± 0.4 ‰, 1σ, n = 23), and the Coppergate individuals also lie within this range. The range of $\delta^{18}O$ values for Masham is 1.8 ‰ which is not unusually large for the indigenous residents of a community (Evans et al., 2006, Montgomery et al., 2009) given the variation in ingested water $\delta^{18}O$ values produced by boiling, brewing and stewing (Brettell et al., 2012). The oxygen isotope ratios range from 24.7 to 26.5 ‰: such values in human bone carbonate are comparable with those in the bone phosphate of humans originating in central and eastern Britain (Evans et al. 2012) and, for example, with the carbonate oxygen of contemporary burials from St. John's Oxford purported to be a Viking raiding party (Pollard et al., 2012). The difference between the mean $\delta^{13}C$ values for enamel and collagen is 6.3 ‰ which is consistent with a terrestrial diet based on C_3 vegetation (Froehle et al., 2010); such a diet was predominant in Britain at this time. None of the results from Masham or Coppergate are inconsistent with local origins in Yorkshire. Neither are they inconsistent with origins in much of eastern Britain, Denmark and southwest Norway according to modern day $\delta^{18}O$ values of European ground water (Montgomery et al., 2009, figure 4). Therefore, like the collagen results, this isotopic dataset does not allow the identification of possible Scandinavian immigrants to Masham and York.

Strontium isotopes were measured in the enamel of eight individuals from Masham and three from Coppergate (Table 5). Selection of the Masham teeth was made on the basis of the plot in Figure 5, principally targeting the teeth that produced peripheral datapoints to test whether the Masham cluster represented the range of variation expected within a single community, or if the dispersal of the $\delta^{18}O$ v. $\delta^{13}C$ dataset encompassed, and thus hid, non-local individuals. Strontium isotope ratios are plotted against $\delta^{18}O$ values in Figure 6. $^{87}Sr/^{86}Sr$ values range from 0.70805 to 0.71487 which, on current evidence, is an unexpectedly wide range of values for humans originating on the sedimentary rocks of eastern England (Evans et al., 2012). Masham is located on the Carboniferous Millstone Grit of the Yorkshire Dales but lies close to the boundary with the Permian limestones, mudstones, siltstones and sandstones to the east (British Geological Survey, 2001). Strontium isotope ratios of food sourced from this range of Palaeozoic sediments is predicted to lie between c. 0.7090 and 0.7120 (Evans et al., 2010). Crown dentine values, which were measured to obtain an indication of the isotopic composition of labile strontium in the burial soil (Montgomery et al., 2007), lie within this range and suggest that a narrower range of ratios could be assigned to the immediate Masham area of 0.7096 to 0.7110. Therefore, a range of 0.7090 to 0.7120 is conservatively suggested for individuals who were living in the wider vicinity of Masham when their tooth enamel mineralised, as shown by the shaded band drawn on the plot in Figure 6. Individuals originating on the lower land in or near the City of York, which is located in a region of Triassic sandstones overlain by extensive glacial and lacrustine drift deposits (British Geological Survey, 1977, 2001), are expected to have a narrower strontium isotope ratio of $0.7090 \leq {}^{87}Sr/^{86}Sr \leq 0.7100$ (Evans et al., 2010, Montgomery et al., 2011, Müldner et al., 2011) which falls within the range expected for the Masham area and is indicated by the dashed box on Figure 6. The strontium isotope ratios of four of the Masham individuals (MSM88 C, MSM88 U, MSM89 I, MSM89 XXIIIa) are thus consistent with being of local origin. All three Coppergate individuals appear not to have originated in the City of York itself. However, two (COPP-36318 and COPP-30944), may have originated elsewhere in Yorkshire as their strontium isotope ratios of c. 0.711 are widely found in individuals from this region (Evans et al., 2012) and can be obtained from biospheres in regions of Palaeozoic sedimentary rocks of Carboniferous, Permian and Triassic date (Evans et al., 2010). These occur widely in the Yorkshire Dales and the North York Moors, although the majority of the flatter land between the two is blanketed with drift deposits as at York itself (British Geological Survey, 1977, 2001). Five individuals (three male and two female) produced values inconsistent with origins local to Masham and York.

One of these five, MSM88 R, who has low $\delta^{13}C$ values compared with the rest of the population (Figure 5), may have originated in a region of marine carbonates such as chalk or limestone, suggested by a $^{87}Sr/^{86}Sr$ value of 0.70805 (Evans et al., 2012). The Yorkshire Wolds to the east of York, the Carboniferous limestone of the Dales to the west are therefore possible places of origin for this individual. Chalk terrains also occur extensively over much of northern Europe, including a significant part of Denmark (Frei and Frei, 2011), therefore we cannot rule out Danish origins for this individual. Of the remaining four individuals, three have $^{87}Sr/^{86}Sr$ values > 0.714. In England, it is extremely rare to find humans or animals with such high strontium isotope ratios (Evans et al., 2012) and there are currently no identified geological terrains which today consistently produce plants, and therefore arable crops, with values above 0.714 (Evans et al., 2010). Granitic rocks, such as those in Scotland and much of Norway, are the most likely source but the oxygen isotope ratios for the same individuals make Scotland and northern Norway unlikely places of origin. Given the historical evidence and the proximity of other Viking burials in the area, it is possible that these individuals, MSM88 AA, MSM88 S and COPP-15548, and possibly MSM88 B, may be Scandinavian immigrants from southwest Norway, as suggested by the combination of their $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values. All four are estimated to be over c.26 years of age.

CONCLUSIONS

The Masham population were buried in a normative manner for the period and comprised a normal attritional population with an unremarkable range of pathological conditions. The four adults from Coppergate were buried in an unusual location within a city well provided with cemeteries, and two of these had a very unusual body position for the period. None of the skeletons had evidence of inter-personal violence, suggestive of Viking raids. Carbon and nitrogen isotope analysis indicated the individuals from Masham and Coppergate ate a similar, terrestrial-based diet throughout their lives, which compares well with that of other English populations from the same time period, but also with some (but not all) Scandinavian groups. However, strontium isotope analysis has shown that at least some Masham individuals were non-local, and originated from a variety of geographical locations. None of the Coppergate individuals' strontium isotope data are consistent with the Vale of York. While equifinality, the fact that the same isotopic values are consistent with Britain as well as large parts of Scandinavia, means that we cannot conclusively demonstrate Scandinavian origins for any of these individuals, two (or possible three) Masham adults and one Coppergate adult originated on ancient granitic terrains which are found in Scotland, Norway and Sweden but not in Yorkshire. The oxygen isotopes might suggest this is more likely to be south western Norway. In addition, one individual from Masham originated on a chalk terrain, such as that found in both Yorkshire and Denmark.

While cultural archaeology can be used to assess the impact of migration on material culture and burial practices, we cannot assume that only (and all of) those who migrated adopted novel practices. It appears that many Scandinavian migrants to northern England were buried in an archaeologically indistinguishable manner from the burials of the indigenous population. Isotope analysis, however, can begin to address the bigger picture and can both identify individuals who migrated and start to quantify the scale of migration. Moreover, it can help elucidate how non-migrants adopt intrusive burial practices to create a shared identity. It is only by investigating the isotopic and burial evidence together that we can start to address the reasons why specific choices were made regarding funerary provision.

Here we have shown that the level of regional migration was higher than expected for the populations at Coppergate and Masham, and that both populations include individuals who may have grown up in Scandinavia. Further studies are needed to investigate the level of regional as well as international migration during the later Anglo-Saxon period, and it is clear that any burials – archaeologically distinctive or not – should be targeted for isotope analyses to further investigate both migration and the creation and manipulation of social identities.

ACKNOWLEDGEMENTS

The authors thank Richard Hall, Ailsa Mainman, Christine McDonnell, Kev Cale, Mary Kershaw, Ros Watson and Anthea Boylston. Analysis of the Masham population was funded by Harrogate Museum and Arts, analysis of the Coppergate skeletons was supported by York Archaeological Trust. Figure 1 was drawn by Dan Bashford. Figure 2 was reproduced with the permission of York Archaeological Trust. Finally, a huge thank you to the Pott and Agill Study Group, a local community archaeology group who petitioned for the full investigation of the Masham remains. Without their efforts, this work would not have been possible, and it was a pleasure to share our results with them all.

AUTHORS' ADDRESSES

Jo Buckberry

Archaeological Sciences

University of Bradford

Bradford, BD7 1DP

Janet Montgomery

Department of Archaeology

Durham University

South Road

Durham, DH1 3LE

Jacqueline Towers

Archaeological Sciences

University of Bradford

Bradford, BD7 1DP

Gundula Müldner

Department of Archaeology

University of Reading

Whiteknights

Reading, RG6 6AH

Malin Holst

York Osteoarchaeology

Ivy Cottage

75 Main Street

Bishop Wilton

York, YO42 1SR

Jane Evans

NERC Isotope Geosciences Laboratory

Nottingham, NG12 5GG

Andrew Gledhill

Archaeological Sciences
University of Bradford
Bradford, BD7 1DP

Julia Lee-Thorp
Research Laboratory for Archaeology and the History of Art
University of Oxford
South Parks Road
Oxford OX1 3QY

REFERENCES

ABRAMS, L. 2000: Conversion and assimilation. In Hadley, D.M. & Richards, J.D. (eds.), *Cultures in contact: Scandinavian settlement in England in the ninth and tenth centuries.* (Turnhout, Brepols.).

ANON (1989) Dixon Keld burial ground Masham. Archaeological watching brief/excavation March 6th - 27th April 1989. Unpublished archaeological report supplied by Harrogate Museums and Arts.

AUFDERHEIDE, A.C. & RODRÍGUEZ-MARTÍN, C. 1998: *The Cambridge encyclopedia of human paleopathology* (Cambridge, Cambridge University Press).

BARNES, E. 1994: *Developmental defects of the axial skeleton in paleopathology* (Niwot, CO., University of Colorado Press).

BARRETT, J.H., LOCKER, A.M. & ROBERTS, C.M. 2004: 'Dark Age Economics' revisited: the English fish bone evidence AD 600-1600. *Antiquity,* 78**,** 618-636.

BARRETT, J.H. & RICHARDS, M.P. 2004: Identity, gender, religion and economy: new isotope and radiocarbon evidence for marine resource intensification in early historic Orkney, Scotland, UK. *European Journal of Archaeology,* 7**,** 249-271.

BASS, W.M. 1995: *Human osteology: a laboratory and field manual* (Colombia, Missouri Archaeological Society).

BEARD, B.L. & JOHNSON, C.M. 2000: Strontium isotope composition of skeletal material can determine the birth place and geographic mobility of humans and animals. *Journal of Forensic Sciences,* 45**,** 1049-1061.

BIDDLE, M. & KJØLBYE-BIDDLE, B. 1992: Repton and the Vikings. *Antiquity,* 66**,** 36-51.

BIDDLE, M. & KJØLBYE-BIDDLE, B. 2001: Repton and the 'great heathen army', 873-4. In Graham-Cambell, J., Hall, R.A., Jesch, J. & Parsons, D.N. (eds.), *Vikings and the Danelaw.* (Oxford, Oxbow.).

BJØRN, A. & SHETELIG, H. 1940: *Viking antiquities in Great Britain and Ireland. Part IV: Viking antiquities in England* (Oslo, H. Aschehoug and Co.).

BRETTELL, R., MONTGOMERY, J. & EVANS, J. 2012: Brewing and stewing: the effect of culturally mediated behaviour on the oxygen isotope composition of ingested fluids and the implications for human provenance studies. *Journal of Analytical Atomic Spectrometry,* 27**,** 77-785.

BRITISH GEOLOGICAL SURVEY (1977) Quaternary map of the United Kingdom South. Southampton, Ordnance Survey/NERC.

BRITISH GEOLOGICAL SURVEY (2001) Solid Geology Map UK South Sheet. Southampton, Ordnance Survey/NERC.

BROTHWELL, D.R. 1972: *Digging up bones* (London, British Museum (Natural History)).

BUCKBERRY, J.L. (2004) A social and anthropological analysis of conversion period and later Anglo-Saxon cemeteries in Lincolnshire and Yorkshire. *Department of Archaeology.* University of Sheffield.

BUCKBERRY, J.L. 2007: On sacred ground: social identity and churchyard burial in Lincolnshire and Yorkshire, c.700-1100 AD. In Williams, H. & Semple, S. (eds.), *Early medieval mortuary practices.* (Oxford, Oxbow.).

BUCKBERRY, J.L. 2010: Cemetery diversity in the mid to late Anglo-Saxon period in Lincolnshire and Yorkshire. In Buckberry, J.L. & Cherryson, A.K. (eds.), *Burial in later Anglo-Saxon England, c. 650-1100 AD.* (Oxford, Oxbow.).

BUCKBERRY, J.L. & CHAMBERLAIN, A.T. 2002: Age estimation from the auricular surface of the ilium: a revised method. *American Journal of Physical Anthropology,* 119**,** 231-239.

BUDD, P., MILLARD, A., CHENERY, C., LUCY, S. & ROBERTS, C. 2004: Investigating population movement by stable isotope analysis: a report from Britain. *Antiquity,* 78**,** 127-141.

BUIKSTRA, J. & UBELAKER, D.H. 1994: *Standards for data collection from human skeletal remains* (Arkansas, Arkansas Archeological Survey).

COX, M. 2000: Ageing adults from the skeleton. In Cox, M. & Mays, S. (eds.), *Human osteology in archaeology and forensic medicine.* (London, Greenwich Medical Media Ltd.).

CURTA, F. 2007: Some remarks on ethnicity in medieval archaeology. *Early Medieval Europe,* 15**,** 159-185.

DARLING, W.G., BATH, A.H. & TALBOT, J.C. 2003: The O & H stable isotopic composition of fresh waters in the British Isles. 2. Surface waters and groundwater. *Hydrology and Earth System Sciences,* 7**,** 183-195.

DAUX, V., LÉCUYER, C., HÉRAN, M.-A., AMIOT, R., SIMON, L., FOUREL, F., MARTINEAU, F., LYNNERUP, N., REYCHLER, H. & ESCARGUEL, G. 2008: Oxygen isotope fractionation between human phosphate and water revisited. *Journal of Human Evolution,* 55**,** 1138-1147.

ERICSON, J.E. 1985: Strontium isotope characterization in the study of prehistoric human ecology. *Journal of Human Evolution,* 14**,** 503-514.

EVANS, J., CHENERY, C.A. & MONTGOMERY, J. 2012: A summary of strontium and oxygen isotope variation in archaeological human tooth enamel excavated from Britain. *Journal of Analytical Atomic Spectroscopy,* 27**,** 754-764.

EVANS, J., STOODLEY, N. & CHENERY, C. 2006: A strontium and oxygen isotope assessment of a possible fourth century immigrant population in a Hampshire cemetery, southern England. *Journal of Archaeological Science,* 33**,** 265-272.

EVANS, J.A., MONTGOMERY, J., WILDMAN, G. & BOULTON, N. 2010: Spatial variations in biosphere 87Sr/86Sr in Britain. *Journal of the Geological Society, London,* 167**,** 1-4.

FREI, K.M. & FREI, R. 2011: The geographic distribution of strontium isotopes in Danish surface waters: a base for provenance studies in archaeology, hydrology and agriculture. *Applied Geochemistry,* 26**,** 326-340.

FRICKE, H.C., O'NEIL, J.R. & LYNNERUP, N. 1995: Oxygen isotope composition of human tooth enamel from Medieval Greenland: linking climate and society. *Geology Today,* 23**,** 869-872.

FROEHLE, A.W., KELLNER, C.M. & SCHOENINGER, M.J. 2010: Focus: effect of diet and protein source on carbon stable isotope ratios in collagen: follow up to Warinner and Tuross (2009). *Journal of Archaeological Science,* 37**,** 2662-2670.

HADLEY, D.M. 1997: 'And they proceeded to plough and to support themselves': the Scandinavian settlement of England. *Anglo-Norman Studies,* 19**,** 69-96.

HADLEY, D.M. 2000: Burial practices in the northern Danelaw, c.650-1100. *Northern History,* 36**,** 199-216.

HADLEY, D.M. 2001: *Death in medieval England* (Stroud, Tempus).

HADLEY, D.M. 2002: Viking and native: re-thinking identity in the Danelaw. *Early Medieval Europe,* 11**,** 45-70.

HADLEY, D.M. 2006: *The Vikings in England. Settlement, society and culture* (Manchester, Manchester University Press).

HADLEY, D.M. & BUCKBERRY, J. 2005: Caring for the dead in late Anglo-Saxon England. In Tinti, F. (ed.), *Pastoral care in late Anglo-Saxon England.* (Woodbridge, Boydell.).

HALL, R.A. 2000: Scandinavian settlement in England - the archaeological evidence. *Acta Archaeologica,* 71**,** 147-157.

HALL, R.A. (Ed.) (2014) *Anglo-Scandinavian Occupation at 16-22 Coppergate: Defining a townscape,* York, Council for British Archaeology.

HALSALL, G. 2000: The Viking presence in England? The burial evidence reconsidered. In Hadley, D.M. & Richards, J.D. (eds.), *Cultures in contact: Scandinavian settlement in England in the ninth and tenth centuries.* (Turnhout, Brepols.).

HAMILTON, D. 2014: Radiocarbon dating and analysis. In Hall, R.A. (ed.), *Anglo-Scandinavian Occupation at 16-22 Coppergate: Defining a townscape.* (York, Council for British Archaeology.).

HEDGES, R.E.M., CLEMENT, J.G., THOMAS, C.D.L. & O'CONNELL, T.C. 2007: Collagen turnover in the adult femoral mid-shaft: Modeled from anthropogenic radiocarbon tracer measurements. *American Journal of Physical Anthropology,* 133**,** 808-816.

HEDGES, R.E.M. & REYNARD, L.M. 2007: Nitrogen isotopes and the trophic level of humans in archaeology. *Journal of Archaeological Science,* 34**,** 1240-1251.

HILLSON, S. 1986: *Teeth* (Cambridge, Cambridge University Press).

HOLST, M. (2010) Osteological analysis, Coppergate, York. *Unpublished osteological report, York Osteoarchaeology No 1110.*

HOLST, M. 2014: Osteological analysis. In Hall, R.A. (ed.), *Anglo-Scandinavian Occupation at 16-22 Coppergate: Defining a townscape.* (York, Council for British Archaeology.).

İŞCAN, M.Y., LOTH, S.R. & WRIGHT, R.K. 1984: Age estimation from the rib by phase analysis: white males. *Journal of Forensic Sciences,* 29**,** 1094-1104.

İŞCAN, M.Y., LOTH, S.R. & WRIGHT, R.K. 1985: Age estimation from the rib by phase analysis: white females. *Journal of Forensic Sciences,* 30**,** 853-863.

JONES, S. 1997: *The archaeology of ethnicity: constructing identities in the past and present* (London, Routledge).

KOSIBA, S.B., TYKOT, R.H. & CARLSSON, D. 2007: Stable isotopes as ndicators of change in the food procurement and food preference of Viking Age and early Christian populations on Gotland (Sweden). *Journal of Anthropological Archaeology,* 26**,** 394-411.

LANG, J. 2001: *Corpus of Anglo-Saxon stone sculpture volume VI: northern Yorkshire* (Oxford, Oxford University Press).

LEE-THORP, J.A. 2008: On isotopes and old bones. *Archaeometry,* 50**,** 925-950.

LIDÉN, K. & NELSON, E.D. 1994: Stable carbon isotopes as dietary indicator, in the Baltic area. *Fornvännen,* 89**,** 13-21.

LONGINELLI, A. 1984: Oxygen isotopes in mammal bone phosphate: A new tool for paleohydrological and paleoclimatological research? *Geochimica et Cosmochimica Acta,* 48**,** 385-390.

LOVEJOY, C.O., MEINDL, R.S., PRYZBECK, T.R. & MENSFORTH, R.P. 1985: Chronological metamorphosis of the auricular surface of the ilium: a new method for the determination of adult skeletal age at death. *American Journal of Physical Anthropology,* 68**,** 15-28.

LUCY, S. 2005: Ethnic and cultural identities. In Díaz-Andreu, M., Lucy, S., Babić, S. & Edward, D.N. (eds.), *The archaeology of identity: approaches to gender, age, status, ethnicity and religion.* (Abingdon, Routledge.).

LUZ, B. & KOLODNY, Y. 1985: Oxygen isotope variations in phosphate of biogenic apatites, IV. Mammal teeth and bones. *Earth and Planetary Science Letters,* 75**,** 29-36.

MAP ARCHAEOLOGICAL CONSULTANCY (2005) 7-15 Spurriergate, York. SE 6032 5184. Archaeological assessment report. *Unpublished assessment report. Provided by MAP Archaeological Consultancy.* Malton, MAP Archaeological Consultancy Ltd.

MARESH, M.M. 1970: Measurements from roentgenograms. In McCammon, R.W. (ed.), *Human growth and development.* (Springfield, IL, Charles C. Thomas.).

MAYS, S. & COX, M. 2000: Sex determination in skeletal remains. In Cox, M. & Mays, S. (eds.), *Human Osteology in Archaeology and Forensic Science.* (London, Greenwich Medical Media Ltd.).

MEINDL, R.S. & LOVEJOY, C.O. 1985: Ectocranial suture closure: a revised method for the determination of skeletal age at death based on the lateral-anterior sutures. *American Journal of Physical Anthropology,* 68**,** 57-66.

MONTGOMERY, J., EVANS, J.A., CHENERY, C.A. & MÜLDNER, G. 2009: Stable isotope analysis of bone. In Carver, M.O.H., Hills, C. & Scheschkewitz, J. (eds.), *Wasperton: A Roman, British and Anglo-Saxon Community in Central England.* (Woodbridge, Boydell and Brewer.).

MONTGOMERY, J., EVANS, J.A. & COOPER, R.E. 2007: Resolving archaeological populations with Sr-isotope mixing models. *Applied Geochemistry,* 22**,** 1502-1514.

MONTGOMERY, J., GRIMES, V., BUCKBERRY, J., EVANS, J., RICHARDS, M.P. & BARRETT, J.H. in press: Finding Vikings with isotope analysis - the view from wet and windy Islands. *Journal of the North Atlantic*.

MONTGOMERY, J., KNÜSEL, C. & TUCKER, K. 2011: Identifying the origins of decapitated male skeletons from 3 Driffield Terrace, York, through isotope analysis: reflections of the cosmopolitan nature of Roman York in the time of Caracalla. In Bonogofsky, M. (ed.), *The bioarchaeology of the human head: decapitation, decoration and deformation.* (Gainesville, University Press of Florida.).

MOORREES, C.F.A., FANNING, E.A. & HUNT, E.E. 1963a: Age variation of formation stages for ten permanent teeth. *Journal of Dental Research,* 42**,** 1490-1501.

MOORREES, C.F.A., FANNING, E.A. & HUNT, E.E. 1963b: Formation and resorption of three deciduous teeth in children. *American Journal of Physical Anthropology,* 21**,** 205-213.

MORRIS, C.D. 1981: From sword to plough. In Roesdahl, E. (ed.), *The Vikings in England and their Danish homeland.* (London, Penhurst.).

MÜLDNER, G., CHENERY, C. & ECKARDT, H. 2011: The 'Headless Romans': multi-isotope investigations of an unusual burial ground from Roman Britain. *Journal of Archaeological Science,* 38**,** 280-290.

MÜLDNER, G. & RICHARDS, M.P. 2007: Stable isotope evidence for 1500 years of human diet at the City of York, UK. *American Journal of Physical Anthropology,* 133**,** 682-697.

NEALE, N. & BUCKBERRY, J.L. (2008) Osteological analysis of the human skeletal remains from Dixon Keld, Masham, North Yorkshire (MSM 88 and MSM 89). *Unpublished osteological report.* Bradford, Biological Anthropology Research Centre, Archaeological Sciences, University of Bradford.

OGDEN, A.R., PINHASI, R. & WHITE, W.J. 2007: Gross enamel hypoplasia in molars from sub-adults in a 16th-18th century London graveyard. *American Journal of Physical Anthropology,* 133**,** 957-966.

ORTNER, D.J. (Ed.) (2003) *Identification of pathological conditions in human skeletal remains,* London, Academic Press.

PHENICE, T.W. 1969: A newly developed visual method of sexing the os pubis. *American Journal of Physical Anthropology,* 30**,** 297-301.

PHILLIPS, D. & HEYWOOD, B. 1995: *Excavations at York Minster volume 1: from Roman fortress to Norman cathedral* (London, HMSO).

POLLARD, A.M., DITCHFIELD, P., PIVA, E., WALLIS, S., FALYS, C. & FORD, S. 2012: 'Sprouting like cockle amongst the wheat': the St Brice's day massacre and the isotopic analysisof human bones from St John's College, Oxford. *Oxford Journal of Archaeology,* 31**,** 83-102.

RICHARDS, J.D. 2000: *Viking Age England* (Stroud, Tempus).

RICHARDS, J.D. 2003: Pagans and Christians at a frontier: Viking burial in the Danelaw. In Carver, M. (ed.), *The cross goes north. Processes of conversion in northern Europe, AD 300-1300.* (York, York Medieval Press.).

RICHARDS, J.D. 2004: Excavations at the Viking Barrow Cemetery at Heath Wood, Ingleby, Derbyshire. *Antiquaries Journal,* 84**,** 23-116.

RICHARDS, J.D., JECOCK, M., RICHMOND, L. & TUCK, C. 1995: The Viking barrow cemetery at Heath Wood, Ingleby, Derbyshire. *Medieval Archaeology,* 39**,** 51-70.

ROBERTS, C.A. & MANCHESTER, K. 2005: *The archaeology of disease* (Stroud, Sutton).

ROGERS, J. & WALDRON, T. 1995: *A field guide to joint disease in archaeology* (Chichester, John Wiley and Sons).

SCHEUER, L. & BLACK, S. 2000: *Developmental juvenile osteology* (London, Academic Press).

SMITH, B.H. 1991: Standards of human tooth formation and dental age assessment. In Kelley, M.A. & Larsen, C.S. (eds.), *Advances in dental anthropology.* (New York, Wiley Liss Inc.).

SPEED, G. & WALTON ROGERS, P. 2004: A burial of a Viking woman at Adwick-le-Street, South Yorkshire. *Medieval Archaeology,* 48**,** 51-90.

SUCHEY, J.M., BROOKS, S.T. & KATZ, D. 1988: *Instructions for use of the Suchey-Brooks system for age determination of the female os pubis. Instructional materials accompanying female pubic symphyseal models of the Suchey-Brooks system* (Colorado, Distributed by France Casting).

TAYLOR, H.M. & TAYLOR, J. 1965: *Anglo-Saxon architecture. Volume II* (Cambridge, Cambridge University Press).

THURNAM, J. 1849: Description of an ancient tumular cemetery, probably of the Anglo-Saxon period, at Lamel Hill, near York. *Archaeological Journal,* 6**,** 27-39, 123-136.

VAN KLINKEN, G.J. 1999: Bone collagen quality indicators for palaeodietary and radiocarbon measurements. *Journal of Archaeological Science,* 26**,** 687-695.

WENHAM, L.P., HALL, R.A., BRIDEN, C.M. & STOCKER, D.A. 1987: *St Mary Bishophill Junior and St Mary Castlegate* (York, Council for British Archaeology).

YORK ARCHAEOLOGICAL TRUST (1998) Former female prison, Castle Yard, York. Report on an archaeological evaluation. *Unpublished evaluation report. Available at York SMR.* York, York Archaeological Trust.

Table 1: Radiocarbon dates for the Masham and Coppergate skeletons

Skeleton	Sample No.	Radiocarbon Age	Calibrated range (2 sigma)
MSM88 SKL (dentine)	UBA-10012	1248±28 BP	AD 679-868
MSM88 SK M (dentine)	UBA-10013	1116±28 BP	AD 872-1011
MSM89 SK IX (bone collagen)	UBA-9638	1135±23 BP	AD 784-983
COPP 36318 (bone collagen)	SUERC-40423	1272±32 BP	AD 715-885 (combined sample)
	SUERC-41066 SUERC-	1138±31 BP	
	41223	1243±31 BP	
COPP 30944 (bone collagen)	SUERC-40424	1251±32 BP	AD 690-880 (combined sample)
	SUERC-41067 SUERC-	1189±31 BP	
	41224	1246±31 BP	
COPP 30979 (bone collagen)	SUERC-40428	1305±32	AD 670-780 (combined sample)
	SUERC-41068 SUERC-	1253±31	
	41225	1264±31	
COPP 15548 (bone collagen)	SUERC-40429	1252±32 BP	AD 715-890 (combined sample)
	SUERC-41069 SUERC-	1159±31 BP	
	41226	1233±31 BP	
COPP 15548 (bone collagen) (new sample)	SUERC-48324	1083±38 BP	AD 880-1030*

*The initial radiocarbon date for COPP 15548 was not consistent with the stratigraphy and ceramic date, so a new sample was submitted. The new radiocarbon date is preferred by the excavators (Hamilton, 2014, 719)

Table 2: Carbon and nitrogen isotope ratios from bone collagen for Masham and Coppergate humans and Masham animals

Sample	$\delta^{15}N_{AIR}$ (‰)	$\delta^{13}C_{VPDB}$ (‰)	C:N	N(%)	C(%)	Collagen yield (%)
Masham 1988 (MSM88) Human Bone						
SK A	9.8	-20.5	3.3	15.7	43.8	2.4
SK AA	10.3	-19.8	3.2	17.0	45.9	7.7
SK B	9.7	-20.1	3.3	14.8	41.4	3.1
SK BB	11.5	-20.5	3.2	15.7	43.3	1.5
SK C	10.1	-20.6	3.3	15.6	43.5	1.9
SK CC	11.4	-20.5	3.3	15.5	43.2	1.9
SK EE	10.2	-20.9	3.3	13.8	39.5	0.7
SK F	9.8	-20.2	3.2	16.0	43.5	3.0
SK G	11.4	-20.5	3.2	16.3	44.4	5.4
SK GG	10.8	-20.7	3.2	15.0	40.7	1.1
SK H	10.8	-21.1	3.4	13.5	39.1	0.7
SK HH	11.1	-20.6	3.2	16.3	44.3	1.7
SK I	10.7	-20.1	3.1	16.3	43.9	3.0
SK L	11.4	-20.7	3.1	16.5	44.1	2.9
SK M	10.4	-21.0	3.3	14.0	39.7	1.0
SK O	10.1	-20.3	3.2	16.3	44.5	7.1
SK P	10.5	-20.1	3.2	16.3	44.5	5.4
SK S	10.9	-20.3	3.2	16.5	44.9	3.1
SK V	11.4	-20.2	3.2	15.9	43.4	1.8
SK X	10.7	-20.1	3.2	16.1	43.7	2.8
SK Y	9.8	-20.3	3.2	15.9	43.8	2.1
SK Z	10.2	-20.6	3.3	14.5	40.7	1.6
Masham 1989 (MSM89) Human Bone						
SK I	9.7	-20.3	3.2	15.8	43.2	1.6
SK III	9.2	-20.3	3.2	15.7	43.2	2.1
SK V	9.4	-20.6	3.3	14.7	41.4	2.7
SK IX	10.7	-20.0	3.2	15.4	42.6	2.2
SK X	10.8	-20.0	3.2	16.1	43.6	5.3
SK XI	10.8	-20.2	3.3	14.8	41.8	1.1
SK XIIIa	9.2	-20.6	3.2	16.0	43.8	2.3
SK XIIIbi	11.1	-19.5	3.2	15.6	42.5	1.9
SK XIIIbii	12.3	-20.2	3.2	14.9	41.4	1.8
SK XIV	10.3	-20.7	3.1	16.4	44.1	6.7
SK XV	9.3	-20.5	3.2	14.8	41.1	0.9
SK XXI	11.5	-20.7	3.3	15.5	43.5	2.2
SK XXII	9.8	-20.5	3.2	16.4	44.3	3.6
SK XXIIIa	9.9	-20.3	3.2	16.3	43.9	2.7
SK XXIV	10.0	-20.7	3.3	15.1	42.0	2.3
Coppergate Human Bone						

COPP-15548	9.8	-20.4	3.2	16.2	44.4	19.1
COPP-30944	10.1	-20.0	3.2	15.8	43.1	18.2
COPP-36318	11.4	-20.7	3.2	15.8	43.3	18.4
Masham 1988 (MSM88) Faunal Bone						
Sheep/Goat 1	7.4	-21.9	3.4	14.9	43.5	0.7
Sheep/Goat 2	7.5	-22.1	3.4	14.9	43.1	1.0
Sheep/Goat 3	3.5	-21.9	3.5	14.1	40.1	1.1
Pig 1	8.6	-22.1	3.3	15.3	43.4	2.2
Pig 2	7.0	-22.1	3.4	15.1	43.4	2.0
Pig 3	7.4	-22.1	3.3	15.0	42.5	2.1
Cattle 1	6.4	-21.8	3.3	13.7	39.3	1.3
Cattle 2	5.9	-22.0	3.3	14.7	42.1	2.2

Table 3: Carbon and nitrogen isotope ratios from dentine collagen for Masham humans

Sample	Tooth	$\delta^{15}N_{AIR}$ (‰)	$\delta^{13}C_{VPDB}$ (‰)	C:N	N(%)	C(%)	Collagen yield (%)
Masham 1988 (MSM88) Human dentine							
SK AA	17	10.7	-19.9	3.3	14.5	40.5	5.2
SK B	44	9.1	-20.3	3.2	14.6	40.6	4.3
SK C	47	10.8	-20.8	3.3	14.2	39.8	2.6
SK F	38	10.7	-20.1	3.3	14.5	40.5	6.5
SK G	27	10.8	-20.0	3.2	14.5	40.2	3.6
SK HH	47	11.4	-20.4	3.4	13.4	38.5	0.5
SK I	27	10.0	-20.6	3.2	14.1	38.9	2.6
SK M	37	11.7	-20.8	3.2	14.6	40.4	3.7
SK R	24	10.9	-20.5	3.3	13.6	38.7	1.2
SK S	38	12.3	-20.2	3.3	14.1	39.9	4.1
SK U	47	11.4	-20.7	3.2	14.7	40.5	5.2
SK Z	37	10.5	-20.4	3.4	13.2	38.3	0.5
Masham 1989 (MSM89) Human dentine							
SK I	47	10.3	-20.6	3.3	14.4	40.1	4.7
SK XI	47	10.8	-20.3	3.3	14.5	40.6	4.0
SK XIIIb	47	11.7	-20.2	3.2	14.7	40.4	4.9
SK XXII	27	10.1	-20.5	3.3	14.3	40.0	3.5
SK XXIIIa	37	10.1	-20.1	3.2	14.1	39.1	1.8
SK XXIIIai	17	10.5	-20.7	3.2	14.4	39.9	2.8
SK XXIIIaii	48	10.7	-20.7	3.3	14.2	40.1	4.1
SK XXIV	47	10.1	-20.5	3.3	14.1	39.4	2.1

Table 4: Carbon and oxygen isotope ratios from tooth enamel for Masham and Coppergate humans

Sample	Tooth	$\delta^{18}O_{VSMOW}$ (‰)	$\delta^{13}C_{VPDB}$ (‰)
Masham 1988 (MSM88) Enamel			
SK AA *	17	26.0	-13.2
SK B *	44	26.5	-12.8
SK C	47	25.2	-14.7
SK CC	37	25.6	-14.2
SK F *	38	25.6	-13.0
SK G	27	25.7	-13.0
SK HH	47	25.4	-15.1
SK I	27	26.0	-14.6
SK M *	37	25.9	-14.3
SK R	24	25.5	-15.8
SK S	38	26.0	-13.0
SK U *	47	26.0	-15.1
SK Z	37	25.7	-14.7
Masham 1989 (MSM89) Enamel			
SK I *	47	24.7	-13.9
SK XI *	47	25.8	-13.5
SK XIIIa	46	26.2	-14.5
SK XIIIb	47	25.5	-12.8
SK XV	36	25.5	-14.6
SK XXII	27	25.9	-14.4
SK XXIIIa	37	25.7	-13.0
SK XXIIIai	17	24.7	-14.9
SK XXIIIaii	48	26.2	-15.1
SK XXIV	47	25.6	-14.5
Coppergate, York Enamel			
COPP-36318	27	25.0	-13.8
COPP-30944	14	25.6	-14.4
COPP-15548	44	25.5	-14.9

* insufficient enamel for sample replication

Table 5: Strontium isotope ratios and concentration values from tooth enamel for Masham and Coppergate humans

Sample	Tooth	$^{87}Sr/^{86}Sr$	Sr concentration (ppm)
Masham 1988 (MSM88)			
Enamel			
SK AA	17	0.714870	145
SK B	44	0.713200	263
SK C	47	0.710084	82
SK R	24	0.708051	77
SK S	38	0.714290	106
SK U	47	0.711211	80
Dentine			
SK C	47	0.709614	168
SK S	38	0.711063	173
Masham 1989 (MSM89)			
Enamel			
SK I	47	0.709873	104
SK XXIIIa	37	0.709738	55
Dentine			
SK XXIIIa	37	0.709716	112
Coppergate, York			
Enamel			
COPP-36318	27	0.711429	60
COPP-30944	14	0.711749	44
COPP-15548	44	0.714259	75

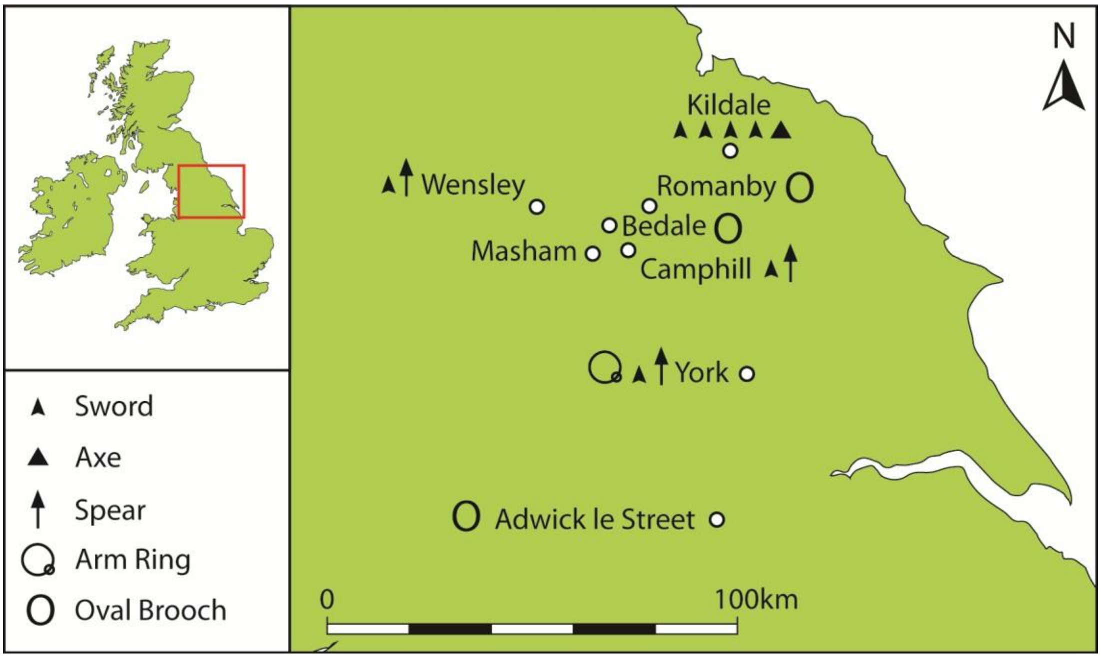

Figure 1: Map of Scandinavian burial sites (drawn by Dan Bashford).

Figure 2: Ninth-century burial from Coppergate, York. The right femur and os coxae have been disturbed post-mortem, however the position of the upper limbs suggest an unceremonial burial (copyright York Archaeological Trust).

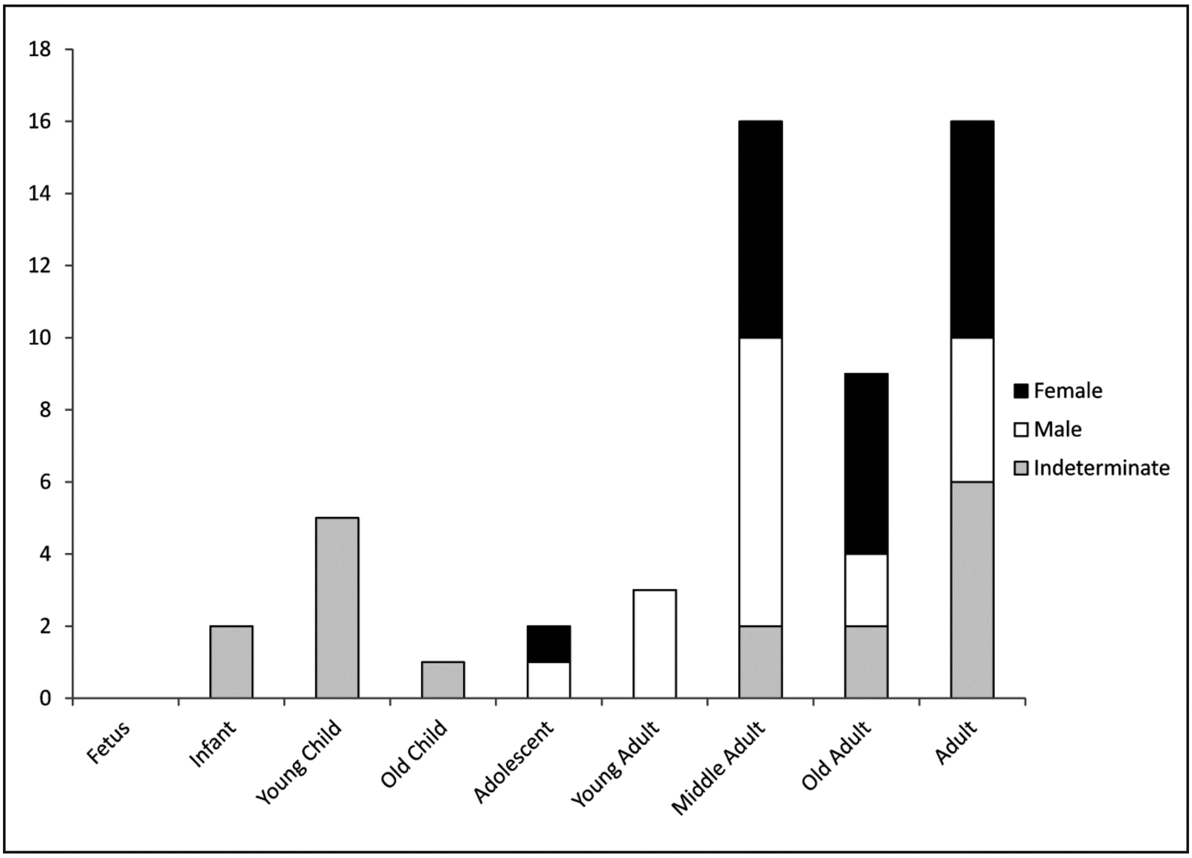

Figure 3: Age and sex structure of the Masham population

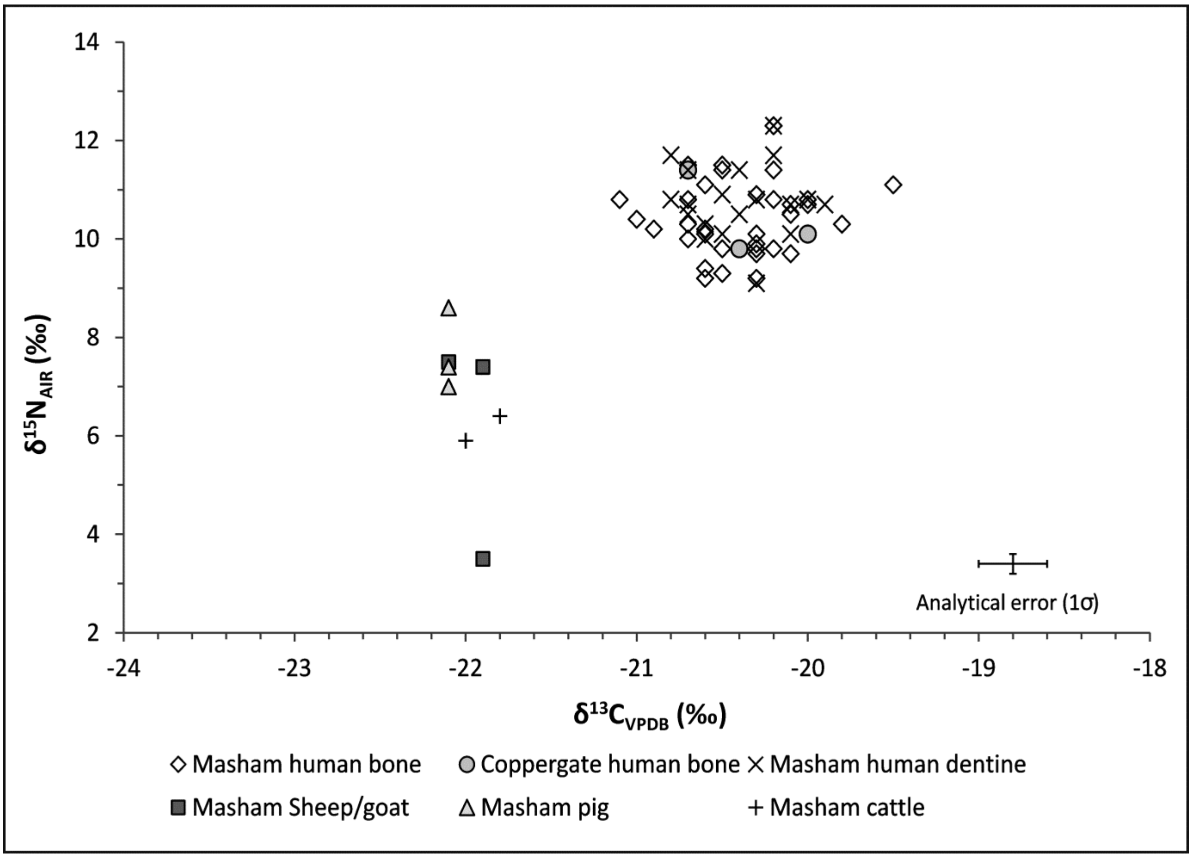

Figure 4. A plot of carbon and nitrogen isotope ratios from bone and dentine collagen for the Masham and Coppergate humans and Masham animals

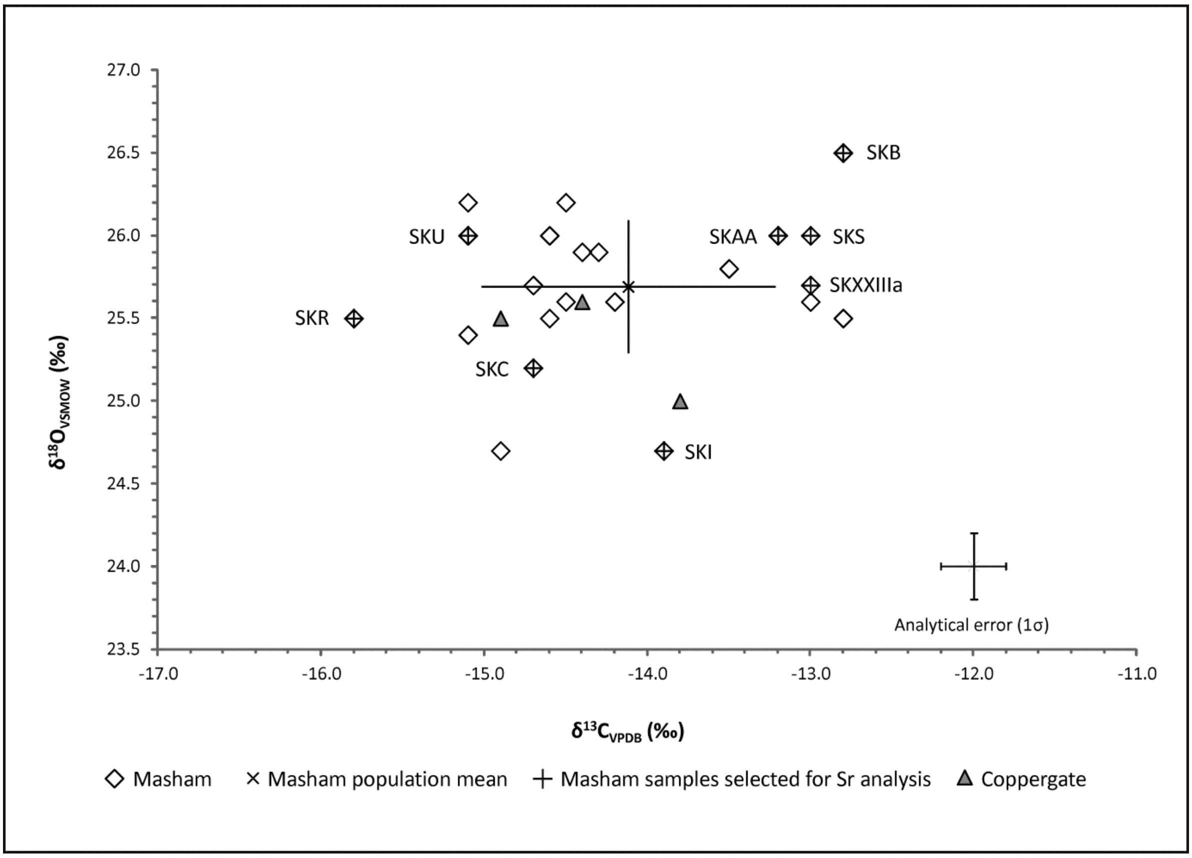

Figure 5. A plot of carbon and oxygen isotope ratios from tooth enamel for the Masham and Coppergate humans. Labelled data points refer to Masham individuals selected for strontium analysis.

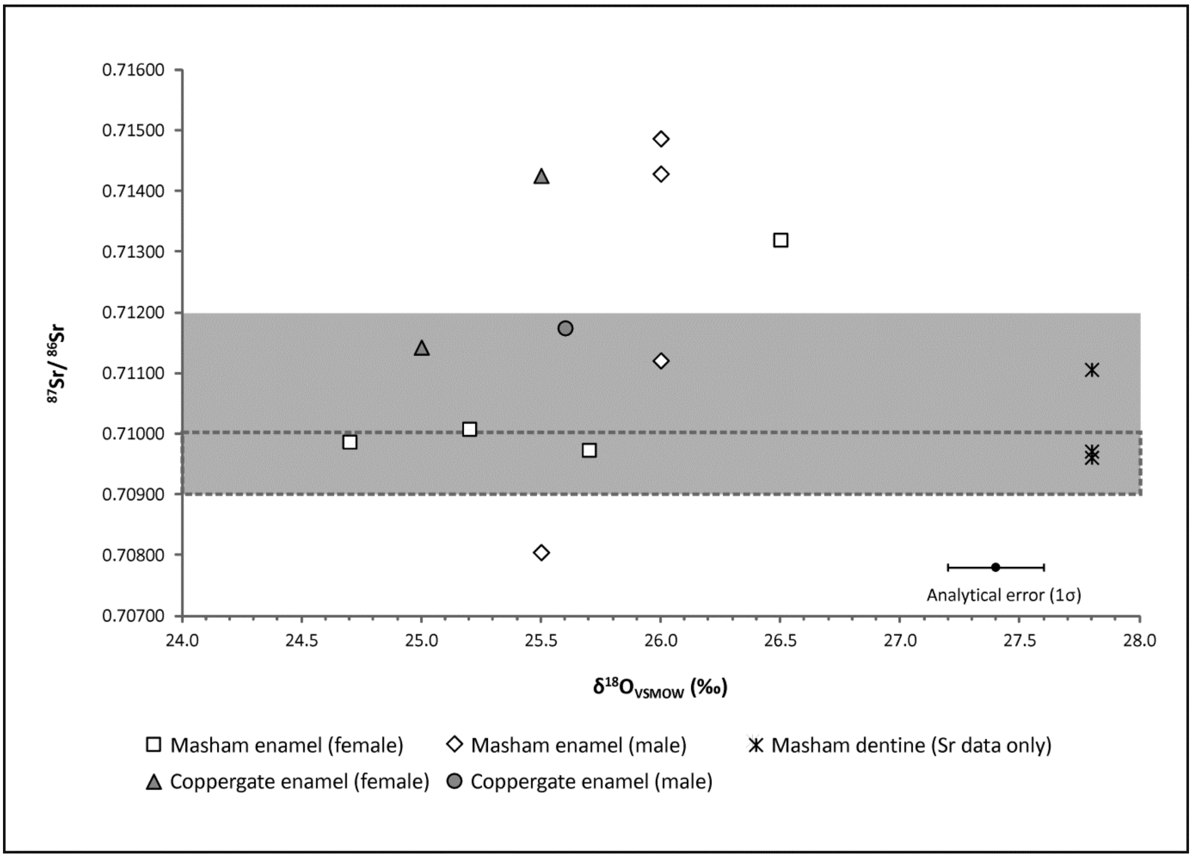

Figure 6. A plot of oxygen and strontium isotope ratios from tooth enamel and dentine for the Masham and Coppergate, York humans. The shaded box represents the estimated strontium isotope biosphere range for the Masham region of North Yorkshire, the dashed box that for York.